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# Science

**Computers, sketch themselves/by Thomas Vasek**

Five years ago in the laboratory of Adrian Thompson at the University of Sussex a small piece of electronics developed. The circuit can differentiate actually only a high from a deep clay/tone, what is not further exciting. Only: How does it make that? No one knows.

For weeks Thompson did and a colleague nothing different one to study than the tangle of the tiny wires. They gave it up sometime. "today we believe to know mostly, what runs off there, says" the electronics-expert Thompson: "nevertheless completely we do not understand it yet."

No humans understand it.

The analysis was a "strange experience", says Thompson: "nearly each day came we with a new theory. But further strangenesses emerged each time, which showed us that we lay wrongly." Today Thompson knows, why: "we thought as electronics designers. But which we had there before us, did not function evenly like a Design developed by humans." Rather one felt reminded of an insect brain.

The mysterious circuit was not made actually by humans. It developed and perfected. If designers a circuit of same function with conventional methods wanted to build chip, one needed ten times so many components according to Thompson.

"Evolvabale hardware" (EHW) is called the forschungsgebiet, which brings such technology out. EHW does not need engineers. It invents itself. The electronic elements develop according to the principles of the biological

evolution. This research area could revolutionize a daily the production of chips, bring in the distant future perhaps even autonomous, adaptive machines out.

Conventional hardware, the physical equipment of a computer, does not change. One cannot simply again wire a conventional chip, if the function does not fit any longer. Evolutionary hardware needs therefore first of all electronics, which can be changed at all - reconfigurable hardware. Gives it such a thing. An example are "Field Programmable Gate Array" (FPGAs, "re-programmable gate stencils").

An FPGA consists of a matrix wired with one another of blocks, which can implement different in each case logical operations. In contrast to a conventional computer chip this Design can be changed however. The valid in each case configuration of a FPGA is determined by bit stringer, thus chains of zeros and ones, which are put down in a memory on the chip. Each new attitude produces in the long run a new small computer.

One can program such FPGA chips in principle with conventional methods, thus "by hand". But "Evolvable hardware" offers a better idea: Why can't one be sketched the chip simply? The principle is to apply to the "configuration bits", thus on the switch attitudes of the chip, so-called evolutionary algorithms - to methods thus, which imitate biological basic principles such as selection and variation.

Evolutionary programming techniques were invented in the sixties. One inserts it today for example use the automatic pattern recognition. Such an algorithm works with computer programs instead of with genetic sequences. One begins it with a population from usually coincidentally produced bit watering gene, steps to the place of the chromosomen. Each of these programs gets a chance to solve the problem posed. In the next step the algorithm evaluates the fitness of the individual programs. The best receive a higher chance to survive - the natural principle of the selection. Stochastic processes lead to innovations: Programs are crossed in pairs, indiscriminate changes of individual bits cause mutations. The most suited programs become generally accepted gradually, while the less suitable go down.

In the EHW uses one on the one hand so-called "extrinsische" methods, which simulate the evolution process only and wire afterwards the result on a chip. More spectacular is meanwhile the "intrinsische" variant, which demonstrated Thompson with its circuit for the first time 1996: The evolution takes place directly in the hardware. For the puzzling circuit for the distinction of tones were necessary over 4000 generations - at the end came out somewhat, which had not seen the world yet.

With EHW one can discover "Designs, on which humans would never come", say Mo she Sipper, computer scientist at the Ben Gurion university into Israel. Human engineers need simplifications, for instance the allocation into modules, in order to control the draft process - nevertheless with it many

alternatives on the distance remain. Evolutionary circuits however profit from large liberty. Their strength lies in it that they function unloaded from prefabricated ideas, says Thompson.

Evolvierte of circuits exploit subtle characteristics of their respective medium. In addition also such count, from which the chip designers notion do not have - for instance errors, which would not affect the function of a conventional chip at all. In it probably also the secret of strange electronics from Adrian Thompsons laboratory lies: The circuit seems to use time delays, which are caused by "parasitic" tensions and resistances on the silicon.

The computer scientist John Koza of the Stanford University, one of the pioneers in the area, has already sieves evolvierte circuits collected, which he calls "human kompetitiv", because they hurt announced patents from humans: They make competition for the inventors.

One can use EHW in particular "for tasks, where one does not get ahead, says otherwise" Uwe seaweeds of the GMD research center for information technology. An example is the draft of similar circuits. They differ from their digital brothers thereby that they can accept continuous conditions, not only 0 or 1; one needs it also in the digital world still, for example of the measurement of continuous sizes such as temperature or tones. Similar circuits to sketch is however complicated and required so far artful manual work. That is awkward, because on the one hand specialists for similar Design, on the other hand are scarce are more error-prone many similar circuits under changing environmental condition than their digital counterparts, which only between two conditions - river or no river - differentiate must. Now hope rests on the fact that the artificial evolution finds a way to the perfection.

In the nano-technology it will not differently go perhaps at all. It is today already possible, individual nano-electronic components in molecular yardstick, logical circuits to build. But the difficulty lies to interconnect many thousands of such components. One will be able "by hand" to manufacture such systems not, says Uwe seaweeds: "you must on their part the correct do."

Another goal of "Evolvable Hardware" is the development of autonomous, fault tolerant systems, which can adapt to changing environmental condition. The Japanese researcher of width unit Tetsuya Higuchi, which leads a EHW working group in Tokyo, developed an evolutionary control mechanism for an artificial hand. The prosthesis learns to adapt itself to the human nerve courses - instead of, as usual, turned around.

A robot, which drills on Mars after water, cannot wait for hardware problems for the technician. Jason Lohn, a researcher at the Ames Research Center of the US space agency NASA in Palo Alto (California), schwaermt therefore of "machines, which program themselves, to assemble and

repair can". NASA wants to develop spaceships, which together-repair themselves, if times somewhat goes wrong. Ar "evolvable hardware immune system" could wappnen for example the on board computers against disturbances by high-energy particles.

At present however the necessary efficiency is missing to evolutionary systems for such applications. One cannot scale it easily: Large, more complicated systems cannot be developed so far. Real time adjustment in a material environment is difficult, because too many factors cooperate. A seizure of power by evolvierte superrobots does not stand for the time being to fear.

Some evolvierte robots can learn of course to run after a ball or to a wall evade. For the everyday life is however too little. Itself a evolvierendes control system would have to try itself out nonstop - in the material world that can be dangerous. Mobile robots cannot afford mistakes. A only one unfit control system could prepare a sudden end for the evolution: If the robot at the firstbest obstacle smashes.

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